Analog Circuits
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Module - 04
Lecture – 03

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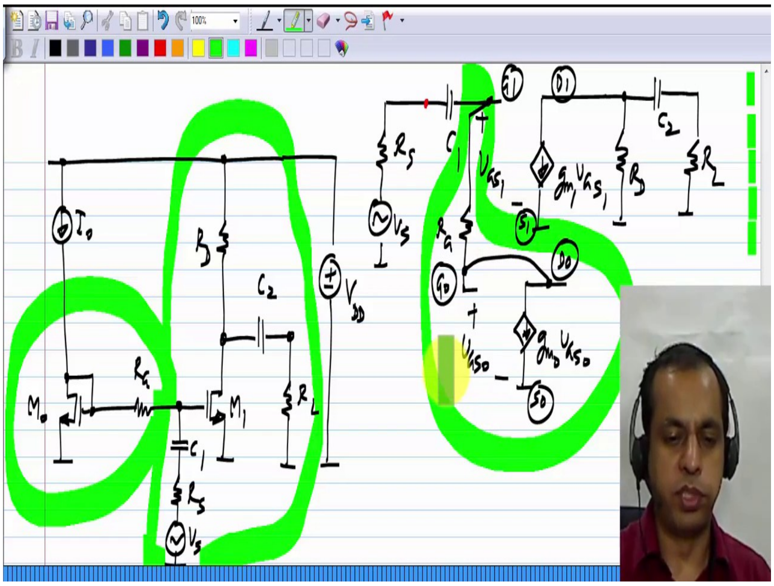

This is our common source amplifier using current mirror bias. Now, it behaves largely like the common source amplifier that we already know, but we will put down the small signal picture of this and analyze it. And also we want to derive the constraints on the capacitors C_1 and C_2, and the resistor R_G. That will do. Now, in the incremental small signal picture, this V_{DD} becomes a short circuit, because there is no change in V_{DD}; V_s will be the only source remaining, and this current source I_0 becomes an open circuit, because there is no increment in the current source itself. This I_0 and V_{DD} are parts of the operating point, and this V_s is the increment.

So, if we do that we have to draw the incremental equivalent of this, first let me draw it for the core components of the common source amplifier. There is something else connected to the gate that I will add on later. So, here, we have V_s, R_s and C_1 and we have the small signal equivalent of the transistor M_1, this is M_1. I will call this $g_{m1}V_{GS1}$, where this is V_{GS1}, and we have the resistor R_D, ac coupling capacitor C_2, and load R_L. By the way, in all these analysis, I am neglecting the incremental output conductance of the transistor itself, but we know that it appears between drain and ground, so eventually it will appear in parallel with R_D and R_L. So, if you do want to analyze it with the output conductance of the MOS transistor it is not at all difficult. So, I will keep it simple and I will omit it for now, but please realize that it will simply appear in parallel with these two. So, wherever you had $R_D || R_L$, you would get $R_D || R_L || r_{ds}$.

Now, we have something else connected to the gate of the transistor that is this point that is this part of the circuit. Now, what is that? From the gate of M_0 to M_1, we have R_G, so let me also label these, this is G_1, D_1 and S_1 meaning that they are gate, drain and source of the MOS transistor M_1. Now, I will have the transistor M_0, so I have $g_{m0}V_{GS0}$, where this is V_{GS0}, and this is gate of transistor M_0, drain of transistor M_0, and source of transistor M_0. And the drain and source of M_0 are connected together. So that connection we have to show.

So, please be very careful while putting down the incremental equivalent circuit of a given circuit, because if you make a mistake there in some connections or by omitting or wrongly connecting some component, the result should be completely wrong. So, this is the new part here, so what we have is this part this R_G in series with something here that is connected to the gate of the transistor. So, let us examine this itself to see what it looks like, that is, we want to find out the incremental equivalent of this part between this gate 1 and through this R_G in series with this all components.

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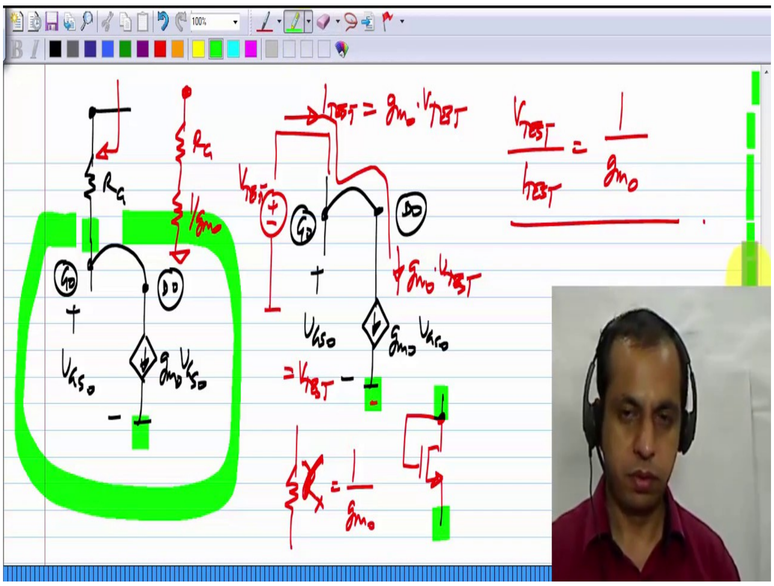

What we have is R_G connected to gate of M_0 and we have $g_{m0}V_{GS0}$, where this is V_{GS0}. And we have the drain and gate connected together. So, between these two points, between this point and ground, it is a two terminal device, that is, this part is a two terminal device and that can be analyzed by itself. We can also analyze it from here, but what we see is the general result, so let us do this. So, this is G_0, D_0, $g_{m0}V_{GS0}$, where this is V_{GS0}. So, now let me apply a test voltage here, V_{TEST} and find the current flowing I_{TEST}. What is it, extremely easy to analyze, this V_{TEST} itself is V_{GS0}, so V_{GS0} equals V_{TEST}, so this current here is g_{m0} times V_{TEST}.

So, this I_{TEST}, it consists of only this current. So, I_{TEST} will be g_{m0} times V_{TEST}. So, the small signal resistance seen between this point and ground is nothing but V_{TEST} by I_{TEST} equals $1/g_{m0}$. So, this whole thing here between this one and that one has an incremental equivalent whose conductance is g_{m0} or the resistance is $1/g_{m0}$. This is, in general, true for a transistor whose drain and gate are connected. So, if you have a transistor like this, and since we consider positive threshold voltage is this will be in saturation region, the equivalent between these two for the incremental signal is a resistor of value $1/g_{m0}$. Now, the equivalent from here is very obvious, it is R_G in series with $1/g_{m0}$. So that is the resistance that we have.

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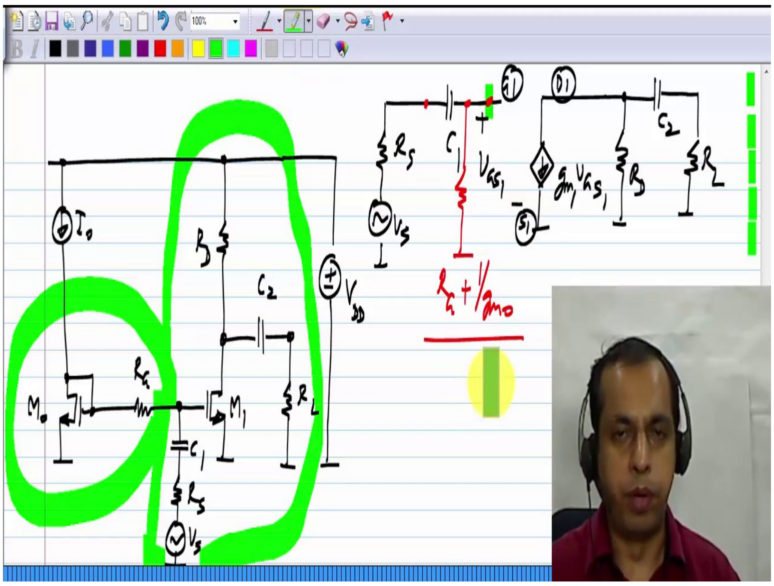

So, now we can replace this entire thing here. The part you have to R_G and M_0 with a single resistor whose value is R_G + $1/g_{m0}$. Now, in a practical common source amplifier, this $1/g_{m0}$ likely to be much, much smaller than R_G, so it can be neglected, but still this result itself is useful to remember, because you will encounter this in many other situations. When you have a transistor in saturation region with its gate connected to the drain, you will have these two terminals and between them you will see an incremental resistance which is $1/g_{m0}$. Now, once we have this equivalent circuit, this picture looks exactly like our old common source amplifier with constant voltage bias. So, we can simply use all of the results from that one.

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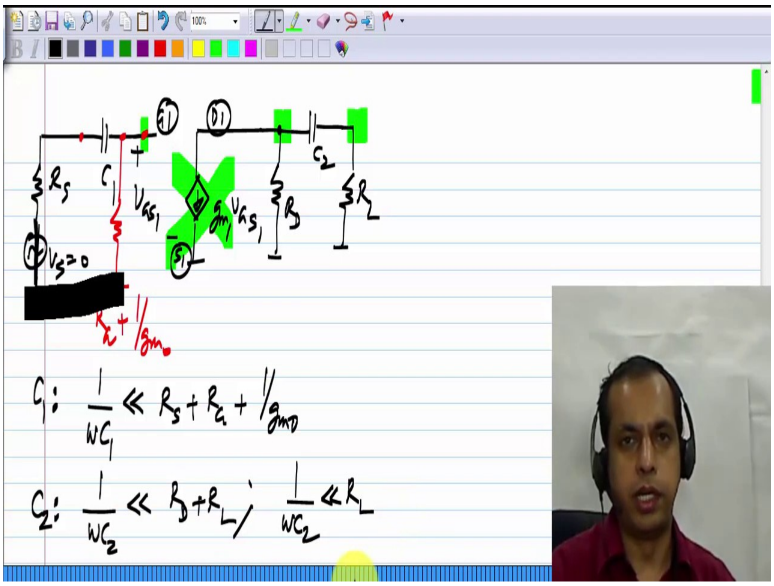

So, I am not going to re-derive the conditions, so for C_1 to appears like a short, the constraint is that the reactance of the capacitor C_1, $1/\omega C_1$ must be much smaller than whatever appears across it after the source is nulled that is V_s is set to zero, so this becomes a short circuit. And what appears across it? If you complete this ground connection, it becomes obvious, it is R_s and this resistance in series. So, $1/\omega C_1$ must be much smaller than R_s + R_G + $1/g_{m0}$. Similarly, for C_2 to appear like a short circuit, it should be such that its reactance is much smaller than whatever appears across it and with the source nulled this current source becomes an open circuit, so this is not there. And what we have are just R_D + R_L, exactly the same result we had from the original common source amplifier. Now, there is an alternative criterion for C_2 as we know that is to make sure that this drain voltage and the load voltage are exactly the same in the incremental sense. So, if you want to have that then $1/\omega C_2$ must be much smaller than R_L.

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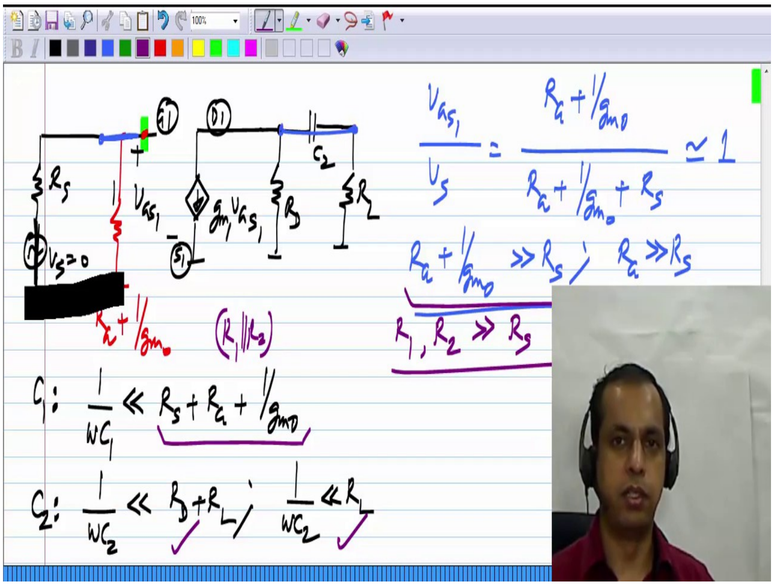

Now, finally, if we satisfy these conditions then we can replace both C_1 and C_2 by short circuits. They are replaced by short circuits. Then what is the voltage that appears as the gate source voltage here? We know that V_{GS1} by V_s is this resistive division, you have R_s here, and this resistance R_G + $1/g_{m0}$. So this ratio is $\frac{R_G+1/g_{m0}}{R_G+1/g_{m0}+R_s}$. And we want this to be approximately one; so if this has to be approximately one then we need R_G+1/g_{m0} or in other words $R_G \gg R_s$, because $1/g_{m0}$ is likely to be much smaller than any of these resistances.

So, I went pretty quickly through this, this is because we have already worked out the results, because if you recall in case of the original common source amplifier, instead of this quantity, what did we have, we had $R_1 \parallel R_2$. And these were exactly the same as before, and we also had a condition similar to this, which was to say that R_1 and R_2 both must be much greater than R_s. So, these conditions are exactly same as for the common source amplifier. So, I hope that is quite easy to understand.